EXTINCTION COEFFICIENT OF LIGHT OF CORES DRILLED AT MIZUHO STATION, EAST ANTARCTICA*

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Abstract: The extinction coefficient of light of shallow ice core samples obtained at Mizuho Station, Antarctica, was measured and its dependences on the depth from 10 m to 110 m, the density in the range of $0.55–0.88 \times 10^3$ kg·m^{-3}, and specific surface area of grains were investigated. The value of extinction coefficient decreased and asymptoted to a definite value with the increase of depth.

1. Introduction

Since the extinction coefficient of light in natural snow is an important factor in investigating the energy and heat balance of a snow cover, a number of measurements have been made by various investigators. ÔURA (1951), LILJEQUIST (1956), THOMAS (1963), and WELLER (1969) measured the extinction coefficient of light in natural snow as a function of depth. They buried sensitive sensors at various depths in snow to measure the rate of decrease of intensity of light and calculated the average value of extinction coefficient of light in snow from the surface to several meters in depth. ÔURA and KOBAYASHI (1965) and KOBAYASHI and ÔURA (1972) measured the extinction coefficient of light in natural snow in the cold room. MELLOR (1965) and KAMIOKA and KUROIWA (1976) measured the extinction coefficient of light in snow artificially prepared under well controlled conditions.

According to the previous paper (KAMIOKA and KUROIWA, 1976), it has been found that the extinction of light in snow is governed mainly by the scattering of light at the interface between air voids and ice grains.

In Antarctica, deposited snow is densified by overburden snow loads and finally turns into glacier ice. This fact means that the apparent density of snow increases and the porosity of snow decreases with depth, reducing the surface area between ice grains and air voids. Therefore, it is interesting to measure the extinction of light in Antarctic firn and to investigate its dependence on depth, apparent density and specific surface area of grains. Japanese Antarctic Research Expedition parties, JARE-12 (1971), -13 (1972), and -16 (1975), made core drilling at Mizuho Station (70°41.9′S, 44°19.9′E) and they succeeded in obtaining core samples (down

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to a depth of approximately 145 m). This paper reports the result of measurement of the extinction coefficient of light in the core samples (JARE-13 cores and JARE-16 cores) obtained from Mizuho Station, Antarctica.

2. Preparation of Specimens and Measurement

The total length of the core samples was 145 m, but deep parts of the core (110 m–145 m in depth) were excluded in our experiment, because they included many cracks or fractures.

Two specimens of snow, 3 cm $\times$ 3 cm $\times$ 5 cm in dimension, were prepared at various depths as shown in Fig. 1a so that the extinction coefficient of light in two directions, vertical and horizontal, could be measured. The experimental arrangement is shown in Fig. 1b. When a light is vertically transmitted through a snow sample, the intensity of light in snow, I at a given depth is expressed by the following formula:

$$I = I_0 \exp(-\lambda h),$$

where I_0 is the intensity of the incident light, h the depth measured from the surface, and λ the extinction coefficient of snow. If we measure the intensity of light in snow as a function of depth h, the value of λ is obtainable. In our experiment, the intensity of light which passed through a sample of core was measured by varying the thickness of the sample.

Fig. 2 shows photographs of vertical thin sections taken under polarized light (left) and vertical cross sections dyed with water blue powder (right) of the core samples at various depths. The grain size was measured from the photograph of thin section and the specific surface area at the air-ice interface was measured from the dyed cross section of the sample, using the method developed by SMITH and GUTTMANN (1953). The photographs of cross sections of core samples dyed with

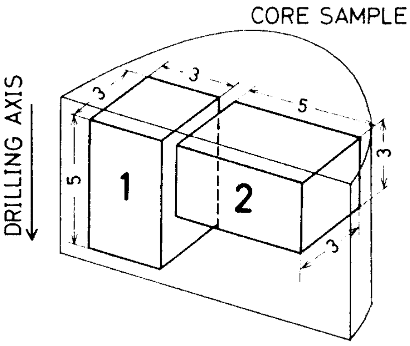

Fig. 1a. Schematic diagram of specimens cut vertically and horizontally.

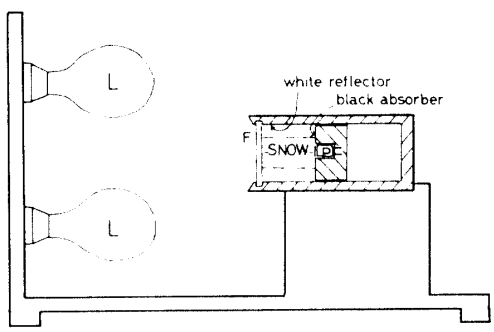

Fig. 1b. Experimental arrangement for the measurement of the extinction of light. L: light source, F: interference filter (800 nm), P: photo-diode sensor.

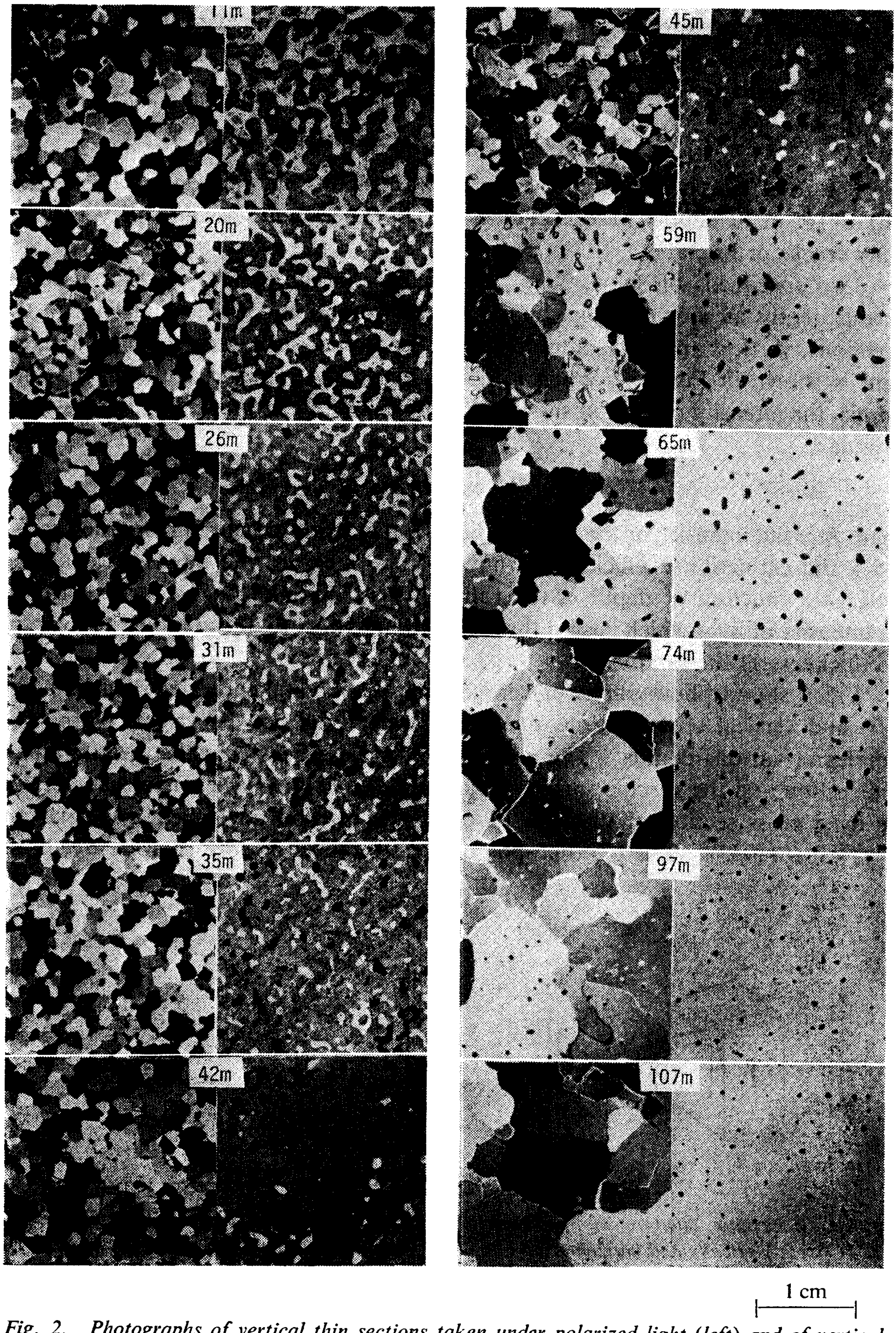

Fig. 2. Photographs of vertical thin sections taken under polarized light (left) and of vertical cross sections dyed by water blue powder (right) prepared at various depths. Water blue dyes only the surface of ice and allows the precise measurement of the specific surface area at the air-ice interface.

water blue powder allowed more precise measurement of the air-ice interfaces than those of thin sections taken through polarized light. As seen in the photographs of thin section (left), the average grain size of the core obtained at the depth of 10 m to 45 m was about 2.0 mm, and that at the depth deeper than 59 m was about 7 mm. As shown in the photographs of cross section (right), the air voids became more spherical with increasing depth and were included within grains. According to our measurement, the specific surface area decreased from 14.0×10^2 $m^2 \cdot m^{-3}$ to 1.7×10^2 $m^2 \cdot m^{-3}$ with depth. A more detailed petrofabric analysis of the structure of the core is given by NARITA *et al.* (1978).

3. Results

Fig. 3 shows values of the extinction coefficient, λ, against the depth. The wavelength of light used in this measurement was 800 nm. As shown in this figure, no difference is discernible in values of λ in two samples cut vertically (open circle) and horizontally (cross) but the extinction coefficient decreased linearly with increasing depth down to 60 m and then asymptoted to the definite value. In this figure, the broken line indicates the depth-density relationship complied by NARITA

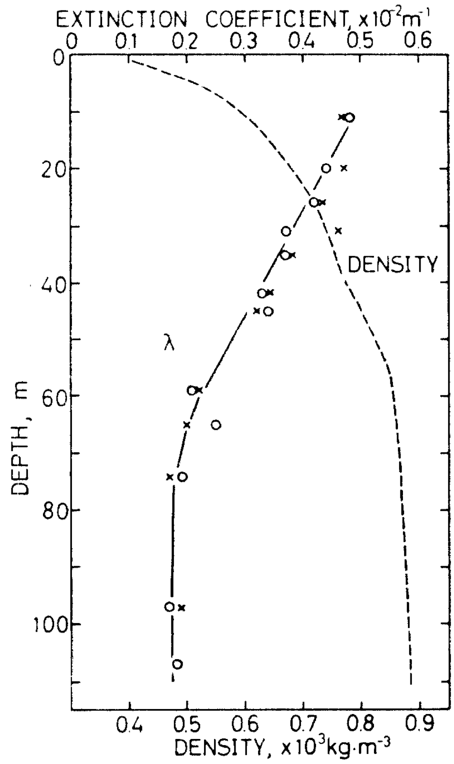

Fig. 3. Values of the extinction coefficient of light for two samples, vertical (open circle) and horizontal (cross) plotted against depth. Broken line indicates the density profile of the core.

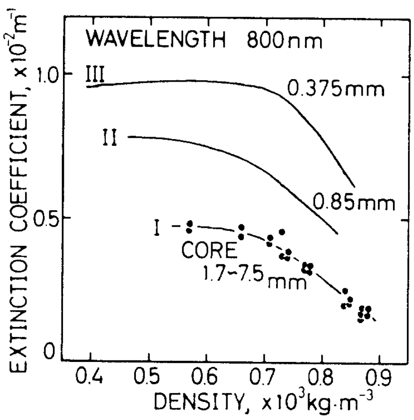

Fig. 4. Extinction coefficient of light of the core sample and artificially prepared snow samples measured as a function of apparent density and grain size. Curve I is for the core, curves II and III artificial snow.

and MAENO (1978).

In Fig. 4, curve I shows the values of extinction coefficient, λ, against the density of the core sample. For the sake of comparison, the density dependence of λ of artificially prepared snow is shown by curves II and III in this figure. The average grain size of artificially prepared snow was 0.85 mm for curve II and 0.375 mm for curve III, while the grain size of the core samples ranged from 1.7 mm to 7.5 mm. As seen in Fig. 4 the extinction coefficient decreased with increasing density, but the value of extinction coefficient of the core was smaller than that of the artificially prepared snow of the same density.

Fig. 5 shows the relation between the extinction coefficients and the specific surface area of grains measured. The value of λ increased linearly with the logarithm of specific surface area in the range of density $0.55–0.88 \times 10^3$ kg·m^{-3}.

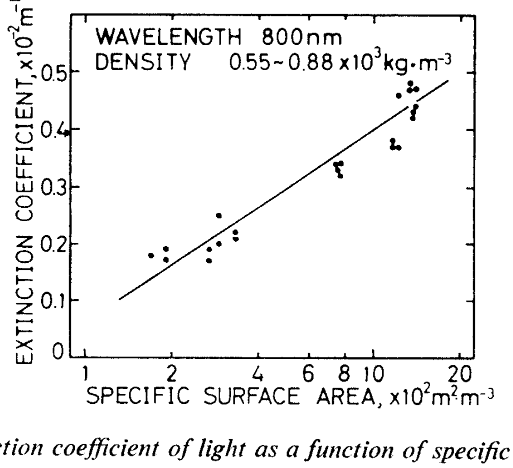

Fig. 5. Extinction coefficient of light as a function of specific surface area.

4. Remarks

YAMADA (1978) has reported that the velocity of ultrasonic wave in Antarctic snow samples in the vertical direction was higher than that in the horizontal direction, and that this difference in the velocity diminished at the depth around 35 m from the surface. Therefore, the anisotropy in value of the extinction coefficient of light was expected for two samples cut vertically and horizontally, but in our measurement no difference in λ-value was found between vertical and horizontal directions as shown in Fig. 3. This may be due to the difference in the mechanism of the propagation between sonic and light waves in snow.

As seen in Fig. 5, the extinction coefficient increased with increasing specific surface area. Fig. 4 also indicated that if the apparent density of snow is the same, the value of λ decreases with increase of the average diameter of grains, because if the apparent density of snow is the same, the specific surface area should be inversely proportional to the grain size.

Though the effect of scattering of light at grain boundaries is not significant in comparison with that at the ice-air interface, further study on the scattering and absorption of light due to grain boundaries must be made in future.

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